forest MANAGEMENT bulletin

SITE PREPARATION — WHY AND HOW

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JUNE 1976

Published by S. E. Area, State and Private Forestry — USDA Forest Service — 1720 Peachtree Rd., N.W. — Atlanta, Georgia 30309

THE NEW FRONTIER

No matter how a site is regenerated to trees — by planting, direct seeding or natural seed fall — some form of site preparation will usually improve survival and growth. This is especially true today when foresters have reached the frontier of "tough" planting sites in the South. The easy acreage is behind us.

Site preparation can be cheap or tremendously expensive. It can be as simple as prescribed burning or as involved as shearing, plus root raking, plus windrowing and burning, plus disking, plus bedding, plus drainage. The best method depends upon the owner's objective, which can be one or more of the following:

- improve early soil moisture conditions by eliminating competing vegetation and excess water.
- improve survival by removing competing vegetation and overhead shade.
- make tree planting easier by eliminating cull hardwoods or logging debris.
- increase wood production.
- improve early growth so the first thinning for wood products can be made earlier.
- shorten length of harvest cycle or rotation.
- optimize financial returns.
- improve wildlife food and cover.
- improve accessibility for firefighting and logging equipment.
- reduce fire hazard.

METHODS

Disking, furrowing and bedding are valuable site preparation methods, but:

- Do not plant in furrows when the water table is close to the surface. Water standing in the furrows or very close to the surface will inhibit root growth and possibly kill the seedlings.
- Do not furrow light, sandy soils. Survival is usually improved but, because top soil is removed, growth is reduced over the long haul.
- Always disk and install furrows on contours to reduce erosion. Avoid complete disking of slopes of 10 percent or more. Provide frequent water outlets so that water will not stand in furrows.

Slash pines grew significantly taller and larger in diameter when planted on furrowed, flat-disked, or mound-disked plots than those planted on unpre-

The effectiveness of minimum site preparation by strip disking is demonstrated in this successfully planted area.

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pared plots. These differences become apparent in only 5 years on slash pines grown on Beauregard silt loam in southwest Louisiana. The same treatments improved diameter growth of loblolly pine, but differences in height were not significant. The favorable response can be attributed to control of grass competition.

A study of flatwoods soils in northwest Florida shows that 5-year-old slash pine benefit from disking or disking with bedding. Those disked and bedded grew taller and larger in diameter.

After an 8-year study, one company found that disking alone doubled the cubic foot volume in slash pine plantations on moderately drained sites. Disking and bedding produced additional volume gains. At densities below 900 seedlings per acre, disking and bedding increased volume growth over disking alone by more than 60 percent.

On well drained sites, the same study showed a negative response for both disking and disking with bedding for slash pine. The addition of bedding increased the growth of loblolly only slightly above those grown on sites that had been disked alone.

These and other studies show that bedding has little value for either slash pine or loblolly on well-drained sites. Heavy disks are useful on sites with heavy brush or small hardwoods. This treatment is often used in combination with prescribed fire. Offset disks, in addition to cutting and breaking small material, disturb the root system by pulling at an angle to the direction of travel. The result is generally less sprouting.

In light sod, disking and furrowing usually are not needed. A scalper on the tree planter can remove the grass competition and clear small trash from its path in one operation.

Bedding on excessively wet areas improves drainage, makes planting easier and increases seedling survival and growth.

Bedding is also used to improve drainage and make planting easier. The area to be bedded must be sufficiently free from logging debris and vegetation so a well-shaped bed can be formed. Beds should be sufficiently high to elevate seedlings above standing water. Sites should not be bedded if situated where seedlings would suffer from summer droughts.

Slash pine grows slowly on many poorly drained, sandy soils in the Southeast. During much of the year the water table is so high that growth is retarded, and some stands never reach merchantable size. Drainage, bedding, and fertilization can boost the productivity of such sites. For example, phosphorous fertilizers and bedding influenced the growth of direct-seeded slash pine on three Plummer sand sites that varied in wetness in northwest Florida. On dry and intermediate sites, tree heights were about equal (14 to 15.5 feet) whether on flat-disked strips, beds elevated about 5 inches, or beds elevated about 10 inches. High beds excelled on the wet site. Top dressing with phosphorus at age 2 years stimulated growth by 2 to 5 feet on all seedbeds of the wet and intermediate sites.

On extremely wet, poorly drained sites avoid bedding too far in advance, particularly on sandy soils. Well-shaped elevated beds are difficult to form and tend to slump quicker on these sites.

Beds should be oriented so as to channel water into ditches and natural courses. Except on very flat surfaces, beds should follow contours. Discharge water into vegetated surfaces and avoid bedding on steep slopes if possible. Pines planted on beds in wet areas benefit from improved nutrition and soil aeration.

Chopping is an effective method to reduce woody competition with a minimum of soil disturbance. Generally, a larger chopper is more effective than a smaller one, and two choppers are more effective than one of the same size. If trees are scattered or too large to chop, they can be treated by other methods. The drum chopper functions by uprooting, chopping and compacting material.

For bigger material, a large diameter rolling chopper puts more pressure on the blades with less drag than tandem and tandem-offset drum choppers. For smaller stems the tandem drum chopper has greater cutting action. When choppers are used in an offset (angled) configuration, the roots are also displaced, again reducing sprouting under most conditions. Blades should be kept sharp and re-

placed when badly worn because dull blades require much more pressure to achieve the same cutting action. Cutting action also increases with speed, so choppers should be operated as fast as safety permits. When the ground is soft, chopping is less efficient because the anvil action of firm soil is missing.

Drum chopping reduces competition without removing topsoil or destroying organic matter — important considerations on soils that are low in nutrients.

On fragile sites such as the sand hills in northwest Florida, chopping reduces competiton without removing or destroying topsoil and organic matter. At age 15, slash pine planted on such sites that had been burned and double chopped were twice as tall (30 feet) as those on sites that had been burned and root raked.

Shearing and KG blading is often the best means of removing large numbers of stems too large for disking or drum chopping. Shearing blades are angled or V-shaped, have straight or serrated edges and have a "stinger" for splitting larger trees and stumps (serrated blades are more efficient than straight-edged blades). The blades have a flat sole to allow "floating" on the surface of the ground without digging. The cutting edges and stinger should be sharpened, usually daily, with a portable grinder.

With care, little soil disturbance is necessary and most debris that would hinder planting is removed. If windrows are used on slopes greater than 10 percent, locate them on contour. They should have frequent breaks or aisles for access by planting equipment and firefighting equipment and for deer runs. Large piles and windrows of debris are slow to deteriorate but do not provide cover for wildlife. They also occupy more planting site and result in more loss of topsoil because soil and debris are

Too much topsoil frequently ends up in the windrow of felled trees and debris when bulldozers are used in site preparation.

pushed farther across the ground. To minimize these problems, keep the piles and windrows as narrow as possible. Keep soil out of windrows so surface water will pass through and not develop channels causing gully erosion.

Small piles have some advantages over windrowing. They allow more flexibility in placing material to improve access for fire equipment and roads, for plugging dry gullies, to decrease the possibility of damming surface runoff that might cause seedling mortality and, in some cases, erosion. Piles are also easier to burn. This practice, followed by root raking and disking, has been widely used to convert cutover bottomland hardwood stands to plantations of cotton wood, green ash, sweetgum and sycamore.

Root raking and bulldozing also can be used to remove trees and shrubs. Both treatments have these shortcomings: Considerable top soil ends up in the windrows, and considerable nonproductive time is spent backing away from windrows. The extra traffic also compacts the soil. Where soils are highly erodible, low in nutrients, and on slopes greater than 10 percent, the adverse effects of root rakes and bulldozers may well outweigh any advantages.

In South Arkansas, bulldozing to mineral soil after summer logging virtually eliminated hardwood competition. Three years later, hardwoods overtopped only 7 percent of the area, compared with 23 percent on logged areas that were not bulldozed. At that time, natural pine regeneration stocked 99 percent of the bulldozed area and 63 percent of the other area.

Root rakes usually move less soil into windrows and piles than do bulldozers. A skillful equipment operator can greatly reduce the environmental impact of these tools.

Cultivation generally consists of three or four diskings for 2 or more years to keep down competition from grass and weeds. Hand hoeing, where

tried, proved too expensive. The greatest growth responses have been obtained by combining cultivation and fertilization.

In south Mississippi, cultivation and chemical control of brownspot shortened the grass stage of longleaf. By age four, their heights averaged 7.3 feet — about the same as third-year heights of slash and loblolly.

Intensive cultivation studies in the coastal plain of Georgia, South Carolina and North Carolina also show increased height and total volume for both slash pine and loblolly. The incidence of fusiform rust also increased for both species with the intensity of treatment, but the increase was greatest on slash pine.

Erosion can be a serious shortcoming of intensive cultivation on slopes of 10 percent and greater. Where intensive cultivation is practiced on these steeper slopes, the shorter time mineral soil is exposed, the less soil movement and sedimentation.

Chemicals can be used for individual stem treatment or applied to extensive areas. Soil is undisturbed and litter is not destroyed. However, when chemicals alone are used, machine planting is not practical unless hardwoods are very small or consist of a few widely scattered, large trees.

Individual tree release is best suited to smaller tracts in areas of abundant labor. It is usually accomplished immediately after planting by injection of a herbicide or by felling, with herbicide applied to the stumps.

Foliar application of herbicides by ground or air is usually the cheapest and fastest method of hardwood control. However, this method should be used only when there is no hazard from drift. Be sure to contact State and/or Federal agencies for the latest information on herbicide usage.

Intensive release immediately after underplanting is preferable. In a north Mississippi study, underplanted pines at the end of three growing seasons were 8.8 feet tall where all hardwood competition had been eliminated chemically, 5.3 feet tall where only the overstory hardwoods had been eliminated, and 4.1 feet tall where only the understory had been removed.

Prescribed fire is a valuable supplement to some forms of mechanical or chemical control of competing vegetation. This treatment improves access and visibility — which increase the efficiency and safety of planting operations. Drum chopping and fire, used in combination, are among the most effective and least destructive methods of site preparation. For economy and efficiency, burns should be made as soon after logging or chopping as weather conditions permit. Some drawbacks of prescribed fire are:

- local or State laws may prevent burning during part or all of the year.
- on sites with minimal litter present, fires may be erratic.
- used alone, it will seldom provide lasting benefits.
- it must be used skillfully for safe and effective results.

Nevertheless, fire is the simplest and least expensive method of site preparation. Burns made just ahead of direct seeding bare the soil but also expose seeds to predators. For this reason seed treatment with protective chemicals is essential. Burning prior to direct seeding of loblolly pine on nine tracts in Louisiana and east Texas resulted in average stands of 1,766 seedlings per acre, with 54 percent stocking at age three.

Fertilization can be considered an operational practice only in the poorly drained savannahs, flatwoods and other soils of the Atlantic and Gulf Lower Coastal Plains generally deficient in phosphate. However, the basic knowledge needed to use fertilizers effectively and profitably on much of the forest land in the South is still lacking.

Some idea of the attractiveness of fertilizer and intensive culture can be gleaned from a south Mississippi study in which pine plantations were disked three times each season for 3 years after planting and fertilized 1 year after planting with 100 pounds of N, 50 lbs. of P, and 50 lbs. of K per acre. Cultivation alone increased heights at age five by about 2 feet in slash and loblolly pines, and by more than 1 foot in longleaf. Cultivation and N-P-K fertilizer increased heights by more than 5 feet in longleaf, 6 feet in slash, and 8 feet in loblolly over those only cultivated. Scientists concluded after following this study for 9 years that the rotation could be conceivably shortened 4 years by intensive culture.

Water control should be designed to maintain an optimum water table. In the flatwoods, pines grow best when the water table is at least 18 inches but less than 36 inches below the surface. Ditches designed to follow the natural drainage pattern are usually the cheapest methods of removing excess water. This involves little earth moving and generally results in a minimum of downstream flooding, peat fires, takeover by undesirable vegetation, and disturbance of wildlife. Gating may be needed to

maintain desirable water levels in times of drought and to meter out water during flood periods.

Depth and spacing of ditches will depend upon the surface soil type, depth to pan, and the volume of water. In one North Carolina pocosin, 19-year-old plantations of loblolly had grown about 2 cords per acre per year, within 200 feet of the drainage canals. In contrast, they grew only about 1/7 cord per acre on undrained areas. Benefits from intensive artificial drainage are not only increased volume growth but also decreased soil damage from logging as well as greater accessibility.

Irrigation is presently practical only in some seed orchards. Some idea of the possibilities can be obtained from a south Arkansas study in which sprinkler irrigation supplemented to a level of 2 acre-inches per week, June through October. Trees were fertilized with 100 pounds per acre of 10-20-10 in April and 100 pounds of ammonium nitrate in June. At age 8, the yield per acre in cords was computed as follows: untreated, 8; water only, 12; fertilizer, 17; and water plus fertilizer, 20.

PRECAUTIONS

Public Law 92-500 has set interim goals of "best practical technology" by 1977, and "best available technology" by 1983 for control of nonpoint source pollution. The final goal of "zero discharge" of pollutants is targeted for 1985. What is known about impacts on water quality of various types of mechanical site preparation? For one thing, the primary pollution from site preparation, when it occurs, is sediment. It is also known that the sediment impact depends upon the types of site preparation, run-off characteristics, the recovery period (usually 3-5 years), and the area of treatment in a watershed. For eight river basins in the Southeast, the area experiencing erosion from site preparation ranges from 0 to 4 percent of the forest land. Site preparation, where employed, contributed 30 to 80 percent of the total sediment from forest land.

Soil pedestals around the loblolly seedling indicate excessive soil loss as a result of intensive site preparation too long in advance of planting season.

Table 1. Maximum recommended soil exposure during mechanical site preparation activities 1/

Slope	Maximum Recommended Soil Exposure – Percent	
	Fragile Soils	Stable Soils
0	75	100
5	50	75
10	35	50
15	25	40
20	10	30
25	8	25
30	5	20
35		10
40		5

1/ USFS, 1973. Forest Service Timber Management Manual, 2472.4-6, Region 8 Supplement No. 238.

The impact on water quality depends upon the type of treatment used. In these same river basin studies, various types of site preparation were evaluated for erosion and sediment production rates. Erosion rates were developed from field data, with sediment production rates approximated from the volume of erosion that reached the nearest stream. Chopping produced less than one tenth of the sediment estimated from any treatment involving shearing and bulldozing in the Coastal Plain. In the Piedmont, shearing and disking produced approximately 60 percent as much sediment as resulted from shearing, windrowing and burning. In two basin studies, site preparation was identified as the source of 27 and 57 parts per million (ppm) of suspended sediment. The norm or goal for sediment, in ppm, will vary according to use. The proposed EPA standard for suspended solids is 80 ppm for fisheries while the suspended solids for domestic water supply standard is 10 ppm with a maximum acceptance load of 100 ppm for short periods.

The key to controlling sediment from site preparation is to limit the resulting amount of erosion that must be absorbed by an untreated strip of vegetation, acting as a filter. Three primary factors that determine the amount of erosion are percent of the area with exposed soil, degree of slope and type of soil. The recommended limits of exposed soil by slope and soils are presented in Table 1. If the needed site preparation will not meet these exposure limitations, there are three alternatives: (1) seed with annual grasses to gain needed ground cover to protect the site, (2) select another site preparation treatment and release plantation later by chemical means, and (3) limit use of needed treatment to slopes where the expected soil exposure is accept-

able and use alternative 2 in steeper areas.

The recommended filter strip guidelines will be effective in controlling sediment only if the exposure guidelines are used. Table 2 presents the filter strip guidelines by filter slope and soil stability.

In addition to limiting the amount of exposed soil, filter strips further limit the amount of material reaching a body of water.

Table 2. Recommended horizontal width in feet of filter strips between bottom of site-prepared area and stream or lake 1/

Erosion hazard of strip soil	Percent Slope						
	0 10	20	30	40	50	60
Slight	30 55	80	105	130	155	180
Moderate	40 75	100	140	170	200	235
Severe	50 90	130	170	210	250	290

1/ USFS, 1973. Forest Service Timber Management Manual, 2472.4-6, Region 8 Supplement No. 238.

Management activities need not be eliminated in filter strips but should be modified. The following guide may be helpful.

Acceptable	Avoid
—Felling of timber	—All wheel or crawler vehicles
—Cable skidding	—Roads except at designated crossing
—TSI	—Removal of more than 50% of overstory within one chain of fishable stream
—All regeneration and intermediate cuts	—Log loading areas
	—Mechanical site preparation
	—Prescribed burning

Other precautions to heed:

—Prescribed burners must face up to two problems: Reduction of the amount of particulate matter entering the air, and minimization of the amount of smoke drifting across well-traveled highways.

—Operation of heavy equipment during wet weather on soils with a high clay content can result in serious compaction. Such areas are slow to recover their original structure, slow to revegetate and suffer a reduction in site quality.

—Bedding and drainage canals can make access by fire fighting and logging equipment difficult if some forethought is not given to optimum location or orientation.

—The use of chemicals, particularly in sprays, always poses some threat to agricultural crops and water supplies. Some time spent in educating the public before starting operations is highly worthwhile. Strict adherence to state guidelines and product labelling is essential, as is close attention to the manufacturer's recommendations concerning weather restrictions and hazard to workers at the time of application. All containers should be punctured to prevent reuse and disposed of in a recognized public dump.

COST CONTROL

Initial costs of treatment must be weighed against future returns. Too intensive a treatment may be uneconomical even though the result is an increase in volume. It is essential to get young pines off to a quick start because 63 percent of the height of the dominants and 59 percent of the diameter of the average loblolly and shortleaf pine, at age 50, have been attained in the first 20 years. Furthermore, each additional foot of height at age 30 is roughly equivalent to 1 cord per acre.

Landowners investing in site preparation should be aware that, if they value their money at 8 percent, every dollar invested must return $6.85 at the end of a 25-year rotation or $10.06 at the end of a 30-year rotation just to break even. This does not take into account annual charges which are not affected by site preparation, nor land costs or values which will appreciate in value whether or not trees are present. It does indicate that if you have a choice between a $50 per acre or $100 per acre site preparation treatment, the more intensive treatment must result in the production of $503 more wood at the end of 30 years.

NEW CONSIDERATIONS

Recently developed equipment rapidly and economically harvests pines by pulling them from the ground — taproot and all — like giant carrots. This not only results in an increase of about 20 percent of pulpable tonnage per acre of plantation, but site preparation costs for subsequent planting will be substantially reduced. Also, hazards from the pales weevil should be significantly reduced by removal of stump-taproots from harvested sites. Further, it is possible that infection and spread of *Fomes annosus* may be inhibited in plantations from which stump-taproots are removed, and breeding of pine reproduction weevils may be curtailed. Skidding partially fills most of the holes.

Large mobile chipharvesters are being used to double the aboveground utilization of hardwood stands and to increase the aboveground production

of softwood stands by as much as 60 percent (depending on previous merchantable top diameter). Use of these machines will generally eliminate the need for site preparation techniques devoted to eliminating logging debris and overtopping vegetation. Indeed, most of the sites can be immediately replanted if pine reproduction weevils are not a problem. Some concern has been expressed as to possible deterioration of the site due to removal of the entire tree. This possibility will take several rotations to assess.

Recent results from one Florida study indicate that, for 4 years after treatment, disk harrowing followed by bedding more than doubled the number of plants important for wildlife food and cover. The high occurrence of *Panicums, Paspalums, Andropogons,* and fruit producing shrubs (*Vaccinium* and *Rubus*) form suitable habitat for bobwhite quail, wild turkey and songbirds. Bedding may also offer a greater number of dove, quail and songbird nesting sites than would normal flatwoods because it provides numerous high and dry areas which would not be flooded out during heavy summer storms.

Another Florida study showed that mechanically prepared sandhill sites planted to pine decreased some game food plants. For a 13-year period following drum chopping, plant succession changed the suitability of the site several times. During the first few years, quail and doves prospered while oak mast, important for deer and turkey, was nearly eliminated. As the pines grew, blackberries, desirable for turkey, increased while forbs and cover for quail disappeared. Density of the overstory and the extent fire is used in the stand will affect the later suitability for game.

SITE PREPARATION EQUIPMENT

Equipment	General Description	Limitations and Advantages
Rolling drum choppers	Size varies from 2′ in diameter and 5′ in cutting width to 6′ in diameter and 16′ in cutting width. One make used in tandem has angle or offset configuration. Others have additional blades on rear drum to prevent tracking (blades striking same spot); when filled with water, weights range from 3,000 to over 67,000 pounds.	Tractor pulling power usually exceeded on slopes greater than 25 degrees.
Disk harrows	Sizes vary from 28″ diameter to 50″ diameter disks. Width of cut ranges from 10′ to 15′. Configurations are straight angled and offset in single or tandem. Weights to over 16,000 pounds.	Depending on system, most handle large rocks and stumps better than drum choppers. Drums usually are more effective where there are many standing trees.
Bedding harrows	Heavy duty disk harrows designed to throw dirt inward to form the raised bed; often followed by a rolling hourglass-shaped drum to shape and pack bed. Drum usually has center-mounted coulter.	Most effective with light, rough, or well prepared site.
Shearing blades	Angle and V-blades designed for shearing standing trees. May have stinger for splitting large trees and stumps. Blades have straight or serrated edges. Serrated edges have best cutting action.	Angle blade can be used for piling and windrowing. V-blade works well with other implements such as disks or rolling chopper.
Root rakes	Many models available varying in width, number, size and shape of teeth, blade height, with or without brush racks and center plates. Weights range from less than 1/2 ton to over 3 tons.	Unless used carefully, often result in excessive soil movement and concentration of soil in piles and windrows.

There is no one, *all-purpose site preparation technique. Soil, terrain, vegetative cover, method of regeneration, size of tract, equipment and capital available must be considered. Large landowners with conversion plants can use much more intensive methods than small landowners. Any operation must take into consideration EPA's concern with excessive soil movement and the general public's concern with aesthetics. And remember, early treatment responses have not always indicated long term effects. Use caution in adopting costly practices before results are evident.*

These guidelines were prepared by an interdisciplinary team selected by the Southeastern Area, State and Private Forestry of the U.S. Forest Service. Appreciation is extended to the following field units assisting the team: Weyerhaeuser Company, New Bern, N.C., North Carolina Forest Service, New Bern, N.C., Champion International, Washington, Ga., Continental Can, Washington, Ga., S.E. Forest Experiment Station, Athens, Ga., and Olustee, Fla., University of Georgia School of Forest Resources, Athens, Ga., National Forests in Florida, Lake City, Fla., and Buckeye Cellulose, Perry, Fla.

SUGGESTED READING

1. Balmer, W. E. and Williston, H. L.
1974. Guide for planting southern pines. USDA, Forest Service, SA, State and Private Forestry, 20 pp., illus.

2. Beers, W. L. Jr., and Johstono, H. E.
1974. Intensive culture of slash pine. Proceedings of symposium on management of young pines., pp. 201-211. USDA, Forest Service, State and Private Forestry.

3. Burns, R. M. and Hebb, E. A.
1972. Site preparation and reforestation of droughty, acid sands. USDA, Forest Service, Agric. Handb. 426, 61 pp., illus.

4. Campbell, T. E. and Mann, W. F., Jr.
1973. Regenerating loblolly pine by direct seeding, natural seeding, and planting. USDA, Forest Service, Res. Pap. SO-84, 9 pp., illus.

5. Derr, H. J. and Mann, W. F., Jr.
1970. Site preparation improves growth of planted pines. USDA, Forest Service., Res. Note SO-106, 3 pp.

6. Dinus, R. J. and Schmidtling, R. C.
1971. Fusiform rust in loblolly and slash pines after cultivation and fertilization. USDA, Forest Service Res. Pap. SO-68, 10 pp.

7. Dissmeyer, G. E.
1976. Erosion and sediment from forest land uses, management practices and disturbances in the Southeastern United States. Third Inter-Agency Sedimentation Conference. Denver, Colorado, March, 1976.

8. Grano, C. X.
1971. Conditioning loessial soils for natural loblolly and shortleaf pine seeding. USDA, Forest Service Res. Note SO-116, 4 pp.

9. Hebb, E. A.
1971. Site preparation decreases game food plants in Florida sandhills. J. Wildlife Management, 35 (1):155-162.

10. Koch, P. and Coughran, S. J.
1975. Harvesting taproots of southern pines may boost yields by 20 percent. Forests and People 25 (1):8-11, 38, 39, illus.

11. McKnight, J. S.
1970. Planting cottonwood cuttings for timber production in the South. USDA, Forest Service Res. Pap. SO-60, 17 pp., illus.

12. Malac, B. F. and Brightwell, C. S.
1973. Effect of site preparation on growth of planted southern pine. Union Camp Corp. Woodlands Res. Dept., Note #29, 9 pp.

13. Mann, W. F., Jr. and McGilvray, J. M.
1974. Response of slash pine to bedding and phosphorus application in the southeastern flatwoods. USDA, Forest Service Res. Pap. SO-99, 9 pp., illus.

14. Miller, W. D. and Maki, T. E.
1957. Planting pines in pocosins. J. For. 55:659-663.

15. Mobley, H. E., Jackson, R. S., Balmer, W. E., Ruziska, W. E., and Hough, W. A.
1973. A guide for prescribed fire in southern forests. USDA, Forest Service, SA, State and Private Forestry, 40 pp.

16. Moehring, D. M.
1964. Speeding up growth of the loblolly. Forest Farmer 23(6):9, 13-14, illus.

17. Schmidtling, R. C.
1973. Intensive culture increases growth without affecting wood quality of young southern pines. Can. J. For. Res. 3:565-573.

18. Schultz, R. P. and Wilhite, L. P.
1974. Changes in a flatwood site following intensive preparation. For. Sci. 20(3):230-237.

19. Smith, L. F. and Smith, H. D.
1963. Growth of slash, loblolly and longleaf pine on cultivated sites. USDA, Forest Service Tree Planters Notes 59:1-2, illus.

20. Smith, L. F. and Schmidtling, R. C.
1970. Cultivation and fertilization speed early growth of planted southern pines. USDA, Forest Service Tree Planters Notes 21(1):1-3.

21. Terry, T. A. and Hughes, J. H.
1973. The effects of intensive management on planted loblolly pine (Pinus taeda L.) growth on poorly drained soils of the Atlantic Coastal Plain, Proceedings Fourth North American Forest Soils Conf., p. 351-377. Laval University Press.

22. Ursic, S. J.
1974. Pine management influences the southern water resource. Proceedings of symposium on management of young pines. USDA, Forest Service, SA, State and Private Forestry, pp. 42-48.

23. USDA, Forest Service.
1971. Tractor attachments for brush, slash, and root removal. USDA, Forest Service, ED&T Report 7120-3, 78 pp., illus.

24. USDA, Forest Service.
1975. Slash . . . equipment and methods for treatment and utilization. USDA, Forest Service ED&T Report 7120-7, 47 pp., illus.

25. Williston, H. L. and McClurkin, D. C.
1961. Soil moisture-seedling growth relations in conversion of blackjack and post oak ridges to pine. J. For. 59(1):20-23.

26. Young, H. E.
1975. The enormous potential of the forests — a positive rebuttal to Grantham and Ellis. J. For. 73:99-102.